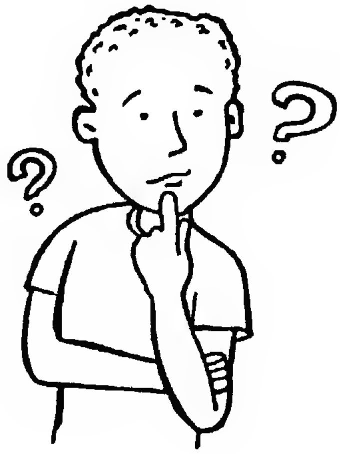
Electronics_1

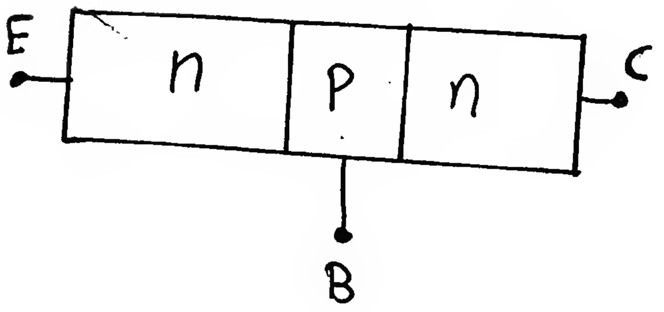


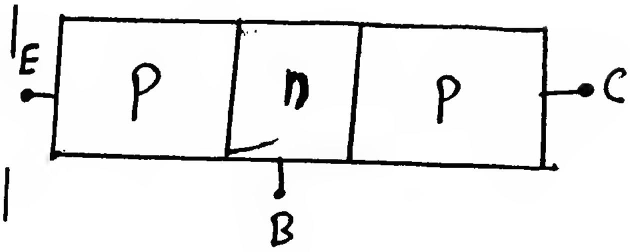
Final Revision

Part (2)

Bipolar Junction transistor
BJT

npn	pnp



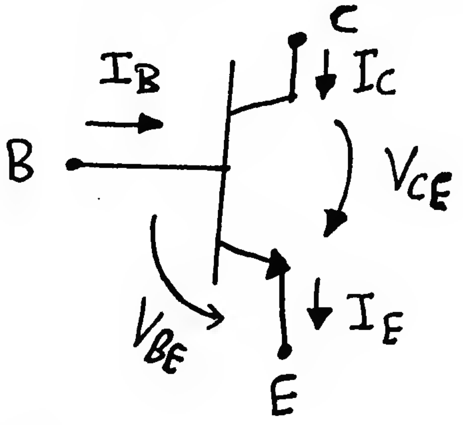


E: emitter, B: base, C: Collector

npn

* Current due to electrons.
(Diffusion)

* Circuit symbol:

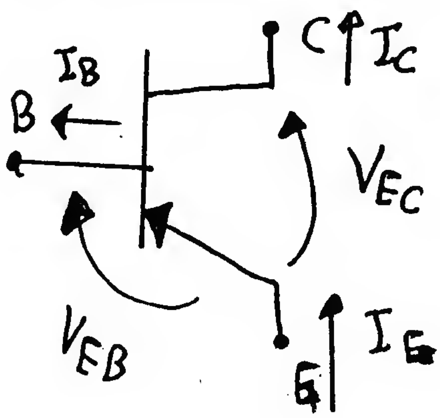


$$I_E = I_B + I_C$$

pnp

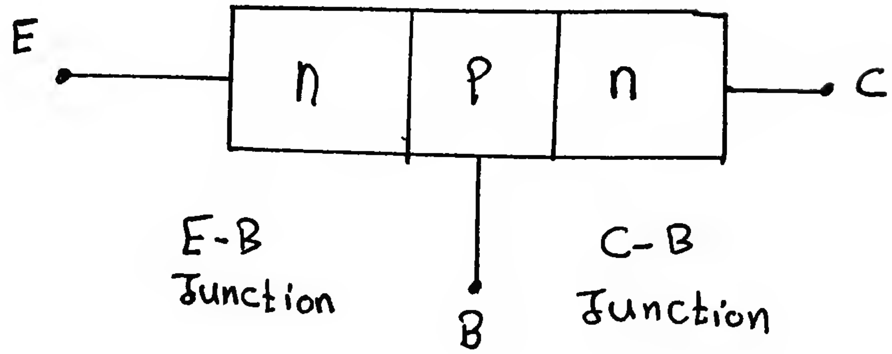
* current due to holes.
(Diffusion)

* Circuit symbol:



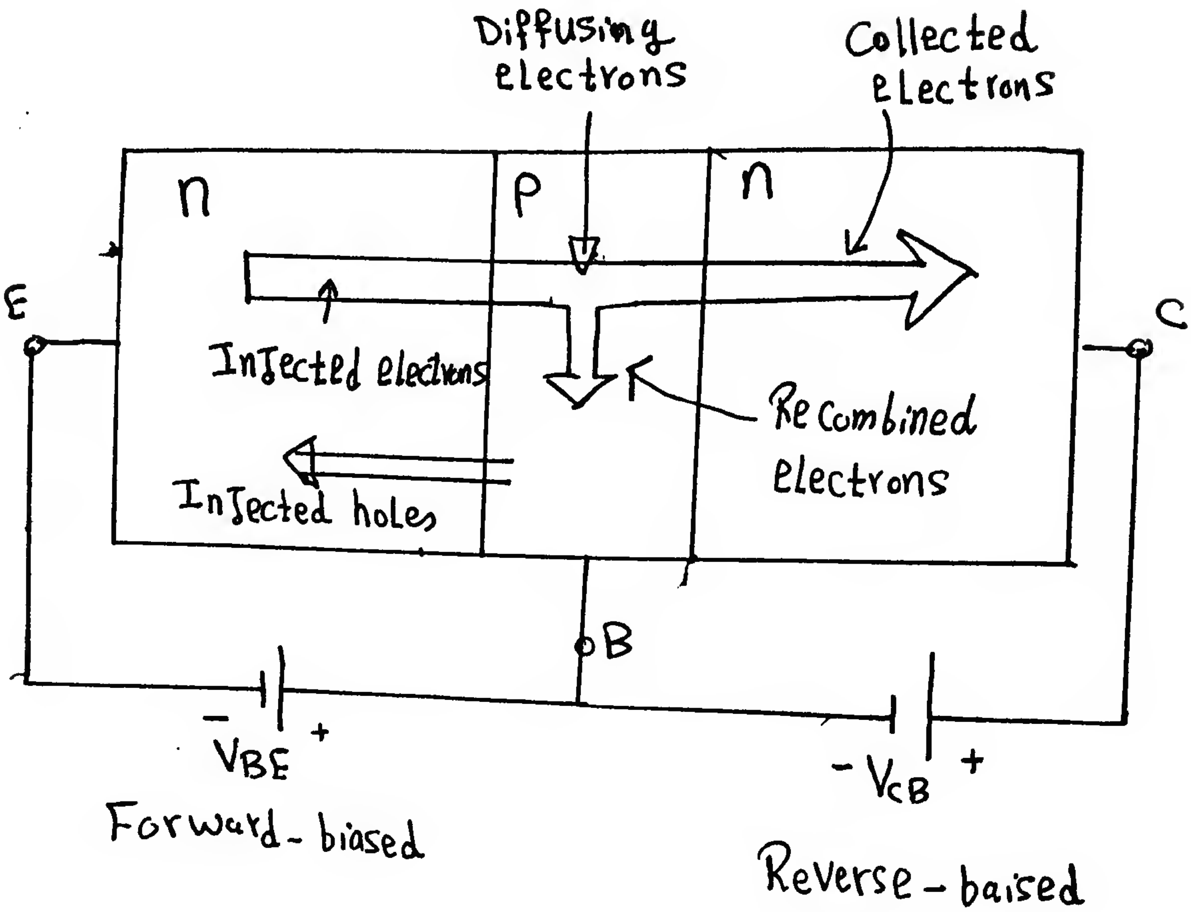
$$I_E = I_B + I_C$$

BJT modes of operation :



E-B Junction	C-B Junction	mode	Application
Forward	Reverse	Active	Amplifier
Forward	Forward	Saturation	S.C
Reverse	Reverse	Cut-off	O.C
Reverse	Forward	Inverse Active	out of this course

* Explain operation of Active mode :



* Electrons are injected from emitter to base.

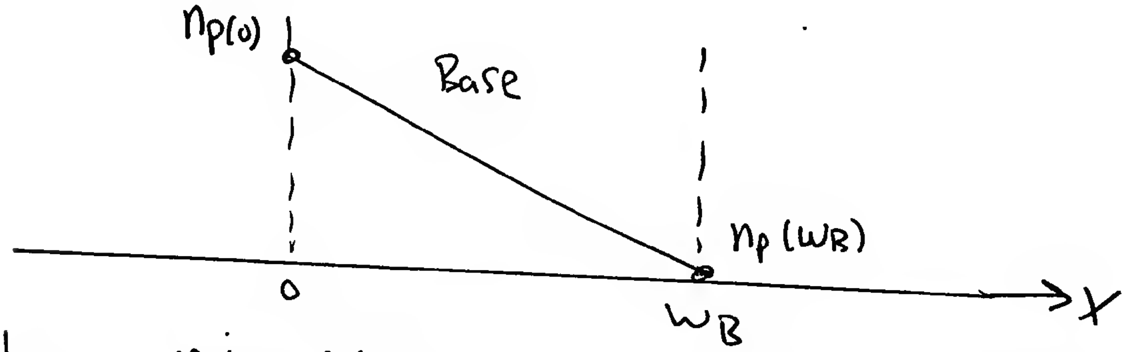
* These electrons moves by diffusion in the base. They moves from the region of high concentration near the emitter towards the region of low concentration near the collector.

* Small number of electrons recombined at base because the base width is small.

* The C–B Junction is reverse biase, So, there is high electric field from n ⟶ p. This field Collects most of electrons to the Collector.
* Holes are Injected from base to emitter

* Proof Equation of I_C in npn BJT (مهم):

$$I_C = q A D_n \frac{dn_p}{dx}$$



$$\frac{dn_p}{dx} = \frac{n_p(0) - n_p(W_B)}{W_B} = \frac{n_{p_0} e^{V_{BE}/V_T} - n_{p_0} e^{V_{BC}/V_T}}{W_B}$$

$$\frac{dn_p}{dx} = \frac{n_{p_0}}{W_B} e^{V_{BE}/V_T} \quad , \quad n_{p_0} = \frac{n_i^2}{N_A} \quad , \quad \frac{dn_p}{dx} = \frac{n_i^2}{W_B N_A} e^{V_{BE}/V_T}$$

$$I_C = q A D_n \frac{n_i^2}{W_B N_A} e^{V_{BE}/V_T} = I_S e^{V_{BE}/V_T}$$

where $I_S = \dfrac{q A D_n n_i^2}{W_B N_A}$ ⋕

* Describe the Components of base current in npn:

1) Recombination of electrons at base

⇒ We Can neglect this term if base width is small enaugh.

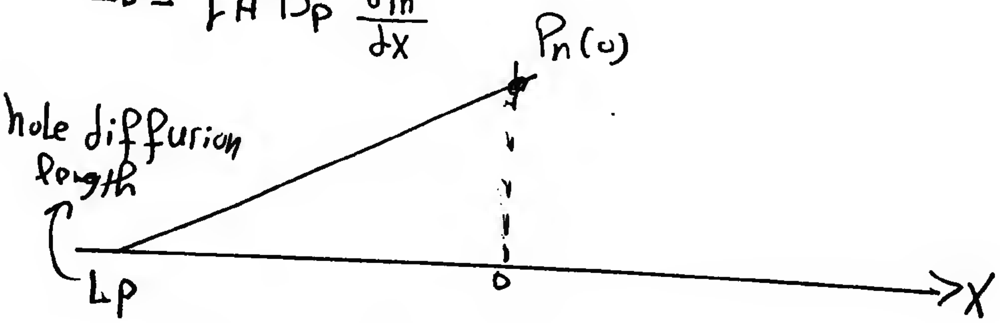
2) InJection of holes from base to emitter

So, the minority Carriers at emitter increases

⇒ diffusion current

* Proof equation of base current in npn BJT:

$$I_B = q A D_p \frac{dP_n}{dx}$$



$$\frac{dP_n}{dx} \approx \frac{P_n(0)}{L_p} = \frac{P_{n0}}{L_p} e^{V_{BE}/V_T} = \frac{n_i^2}{N_D L_p} e^{V_{BE}/V_T}$$

$$I_B = q A D_p \frac{n_i^2}{N_D L_p} e^{V_{BE}/V_T} \quad , \quad I_B = \frac{q A D_p n_i^2}{L_p N_D} e^{V_{BE}/V_T}$$

* Proof that $\beta = \dfrac{D_n L_p N_D}{D_p W_B N_A}$

Sol:

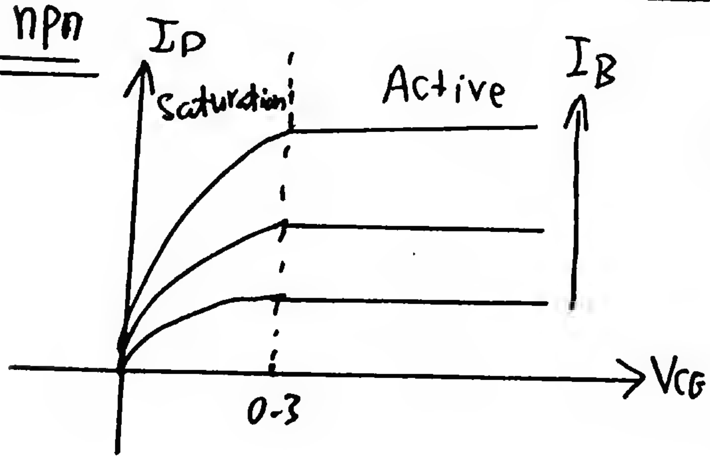
1) Proof that $I_C = \dfrac{q A D_n n_i^2}{W_B N_A} e^{V_{BE}/V_T}$

2) Prove that $I_B = \dfrac{q A D_p n_i^2}{L_p N_D} e^{V_{BE}/V_T}$

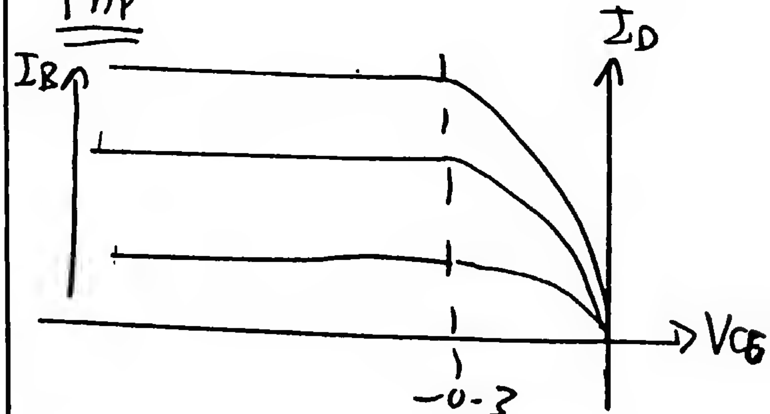
$$\beta = \frac{I_C}{I_B} = \frac{D_n L_p N_D}{D_p W_B N_A} \quad \#$$

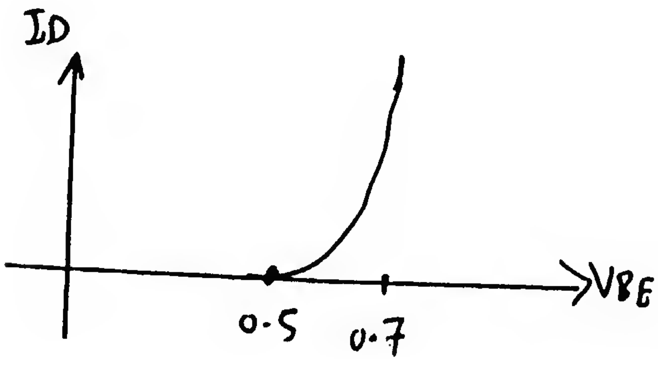
note: $\beta = \dfrac{I_C}{I_B}$, $\alpha = \dfrac{I_C}{I_E}$, $\beta = \dfrac{\alpha}{1-\alpha}$, $\alpha = \dfrac{\beta}{1+\beta}$

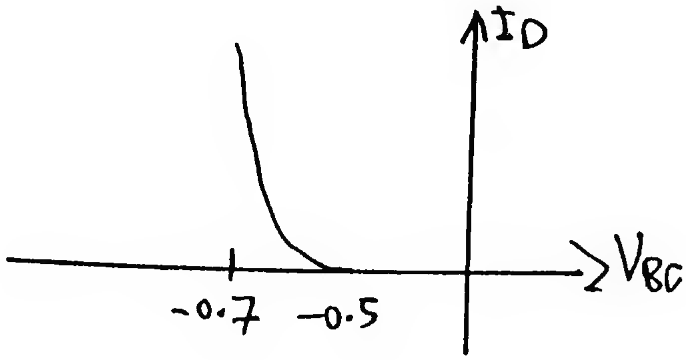
npn



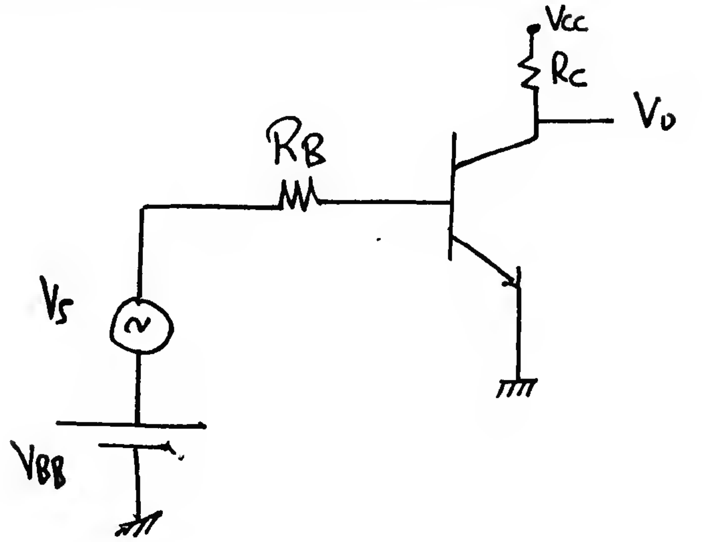
pnp

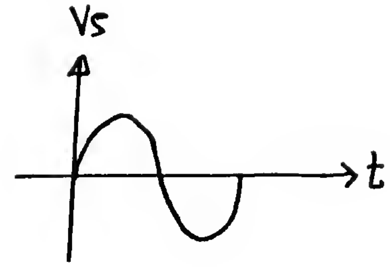






* Maximum Ac swing:

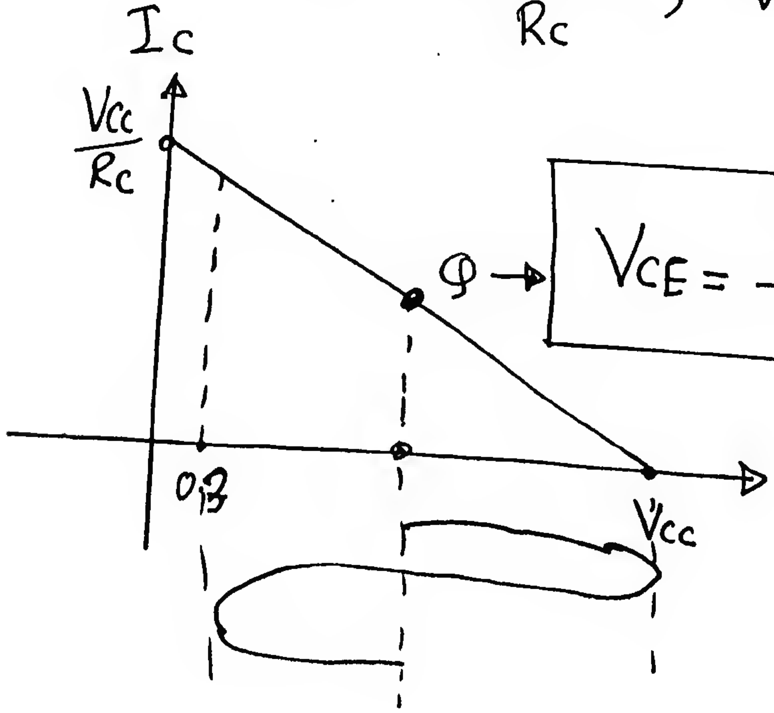




O/P KVL:

$$-V_{cc} + I_C R_C + V_{CE} = 0$$

$$I_C = \frac{V_{cc} - V_{CE}}{R_C}, \quad V_o = V_{CE}$$

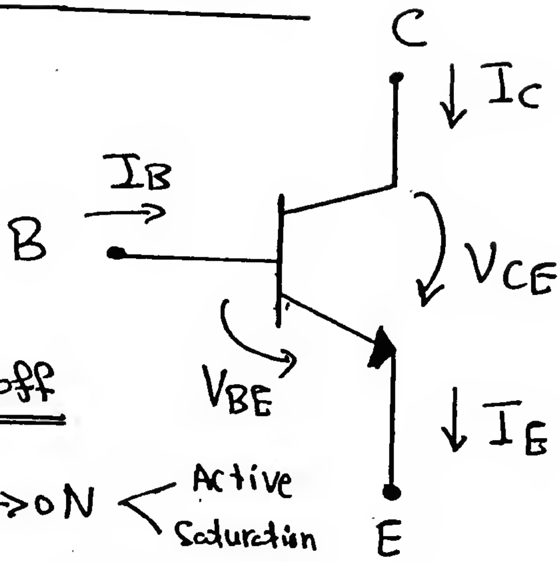


$$Q \rightarrow \boxed{V_{CE} = \frac{V_{cc} + 0.3}{2}} \simeq \frac{V_{cc}}{2}$$

Maximize Ac Swing

⋕

* npn BJT DC analysis



$\beta =$ ___

$V_{BE} < 0.7 \Rightarrow$ off

$V_{BE} \geq 0.7 \longrightarrow$ ON < Active / Saturation

Assume Active

$I_C = \beta I_B$, $I_E = (\beta + 1) I_B$, $V_{BE} = 0.7$, $\underbrace{V_{CE} > 0.3}_{\text{Check}}$

If $V_{CE} < 0.3 \longrightarrow$ Assume saturation:

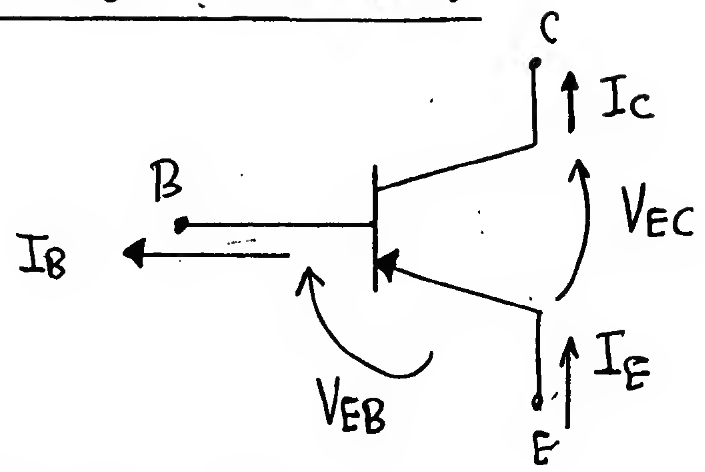
$V_{CE} = 0.3$, $I_E = I_C + I_B$

$I_C < \beta I_B \longrightarrow$ check

$V_{BE} > 0.8 \rightarrow$ Check

Note: Very high β or infinite β means $I_B = 0$, $\boxed{I_C = I_E}$

* PNP BJT DC analysis:



$V_{EB} < 0.7$ off

$V_{EB} \geq 0.7 \longrightarrow$ ON $\rightarrow$ Active / Saturation

Assume Active:

$I_C = \beta I_B$, $I_E = (\beta+1) I_B$, $V_{EB} = 0.7$, $\underbrace{V_{EC} > 0.3}_{\text{Check}}$

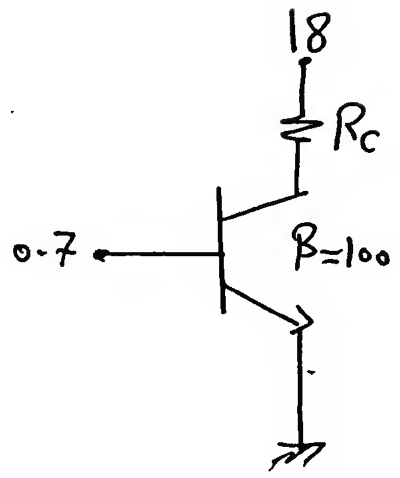
If $V_{EC} < 0.3 \longrightarrow$ assume Saturation

$V_{EC} = 0.3$, $I_E = I_C + I_B$

$I_C < \beta I_B \longrightarrow$ check

$V_{EB} > 0.8 \longrightarrow$ check

Pb (2030)

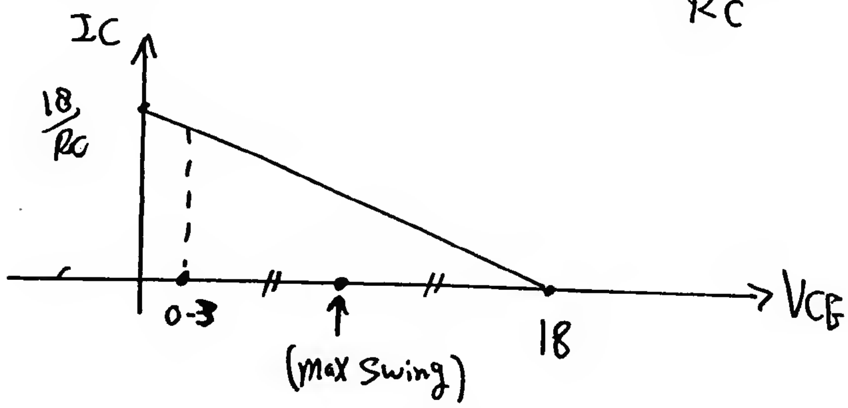


* Find R_C for maximum symmetric output swing given that $I_B = 100\mu A$

Soln

o/p KVL

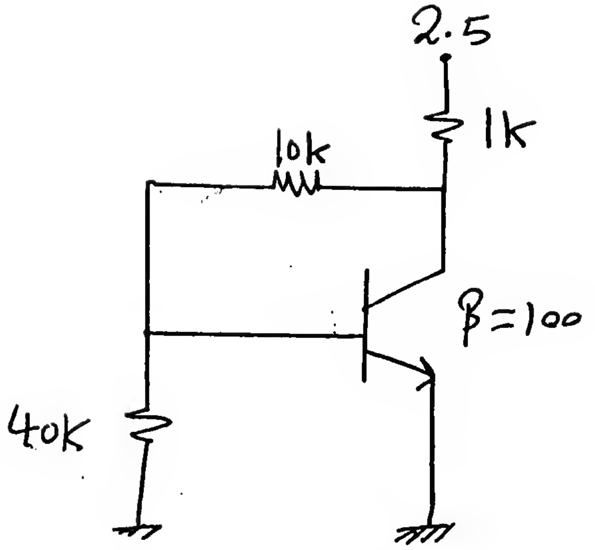
$$-18 + I_C R_C + V_{CE} = 0 \longrightarrow I_C = \frac{18 - V_{CE}}{R_C}$$



$$V_{CE}\Big|_{max\text{-}swing} = \frac{18+0.3}{2} \simeq \frac{18}{2} = 9V \,, \quad I_C = \beta I_B = 10\,mA$$

$$R_C = \frac{18-9}{10} = 0.9\,k\Omega \quad \#$$

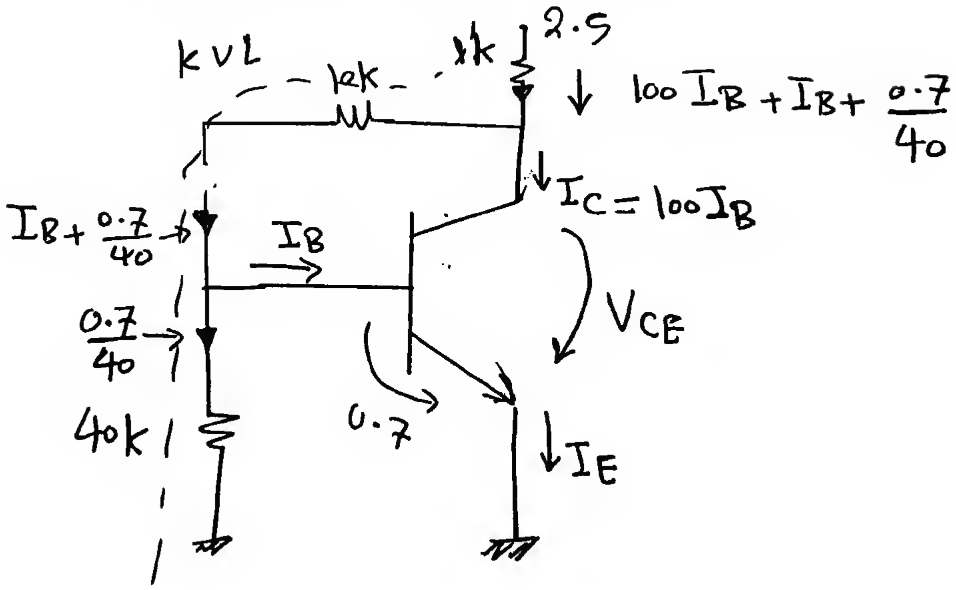
P6



Find Q-Point

Soln Assume Active :

$V_{BE}=0.7$, $I_C=100 I_B$, $I_E=101\, I_B$, $V_{CE}>0.3$



KVL :

$$-2.5 + \left(101 I_B + \frac{0.7}{40}\right)(1) + \left(I_B + \frac{0.7}{40}\right)(10) + 0.7 = 0$$

$I_B = 14.48\,\mu A$

$I_C = 1.448\,mA$

$I_E = 1.4626\,mA$

O/P KVL :

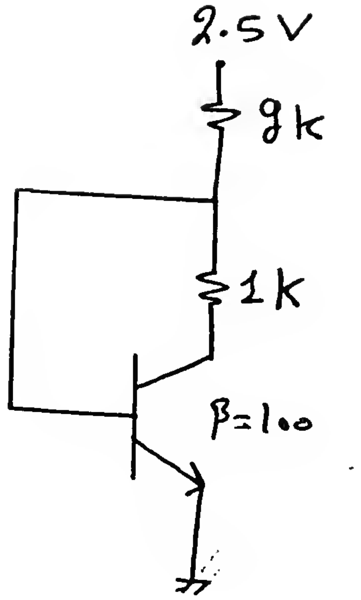
$$-2.5 + \left(101\,(14.48\,\mu A) + \frac{0.7}{40}\right) + V_{CE} = 0$$

$\therefore V_{CE} = 1.02\,V > 0.3 \Rightarrow$ Active

Q-Point $\left(I_C = 1.448\,mA,\ V_{CE} = 1.02\,V\right)$

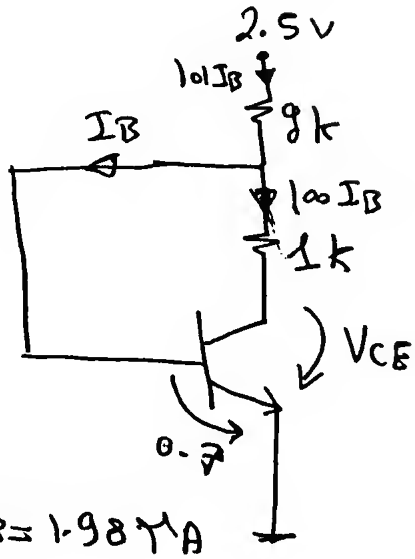
$\left(I_B = 14.48\,\mu A,\ V_{BE} = 0.7V\right)$

P6



Find Q-point

Soln



assume active:

$I_C = 100 I_B$, $V_{BE} = 0.7$

$V_{CE} > 0.3$

E-B KVL

$-2.5 + 101 I_B * 9 + 0.7 = 0 \Rightarrow I_B = 1.98 \mu A$

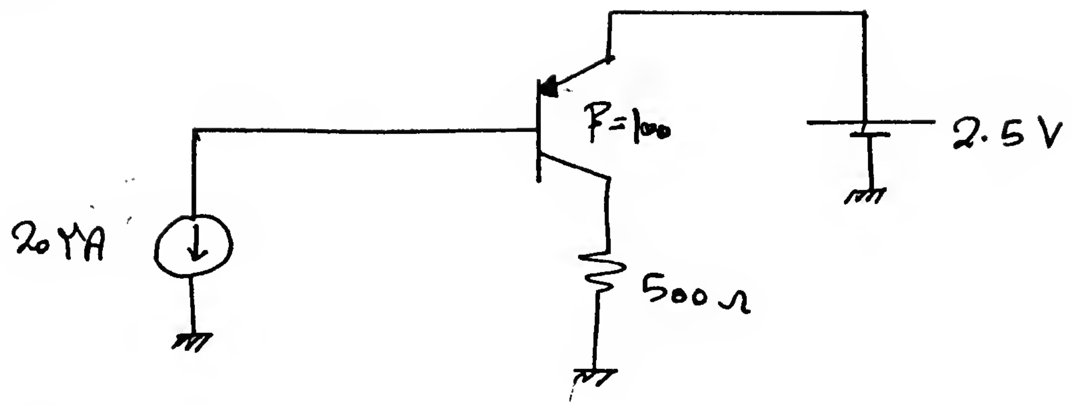
O/P KVL:

$-2.5 + 101(1.98 * 10^{-3}) * 9 + 100(1.98 * 10^{-3}) + V_{CE} = 0$

$V_{CE} = 0.5 > 0.3 \Rightarrow$ Active

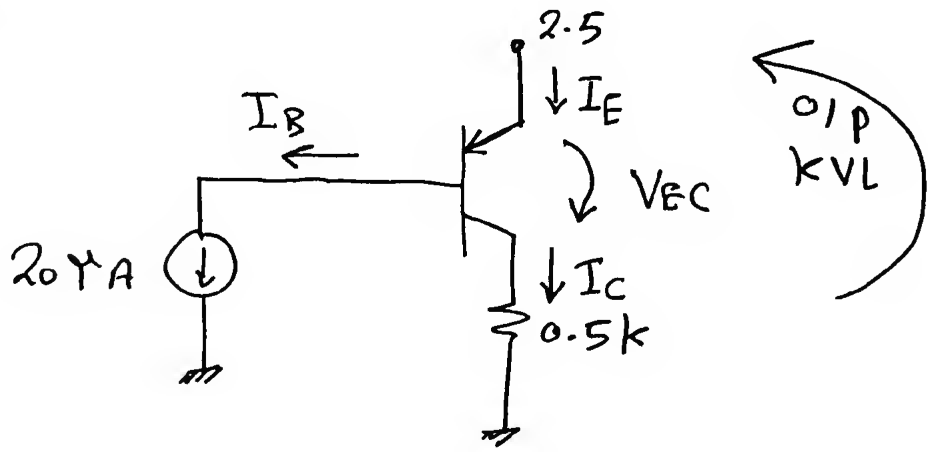
$I_C = 0.198\ mA$

P6



Find Q-Point & Determine mode of operation.

Soln



Assume Active

$I_C = 100 I_B$, $V_{EB} = 0.7$, $V_{EC} > 0.3$

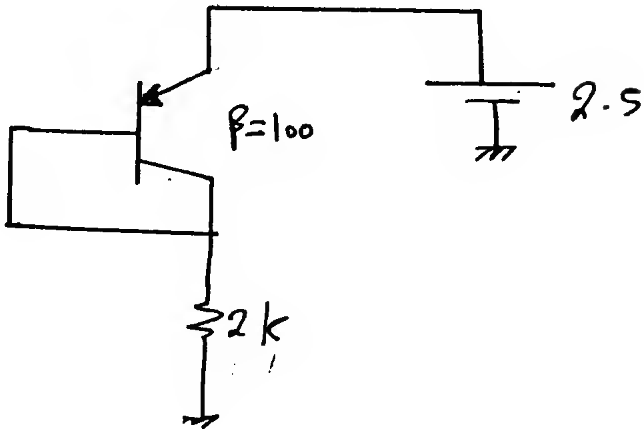
$I_C = 100 * 20\mu A = 2\ mA$

o/p KVL : $-2.5 + V_{EC} + 0.5(2) = 0$

$V_{EC} = 1.5 > 0.3 \Rightarrow$ Active

Q-Point ($I_C = 2mA$, $V_{EC} = 1.5V$)
($I_B = 20\mu A$, $V_{EB} = 0.7$)

Pb

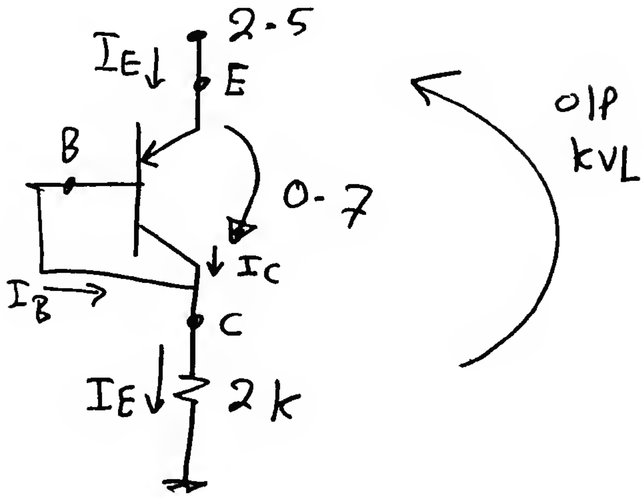


Find Q-Point

Sol^n

$$V_{EC} = V_{EB} = 0.7 > 0.3 \Rightarrow \text{Active}$$

O/P KVL :



$$-2.5 + 0.7 + 2 I_E = 0$$

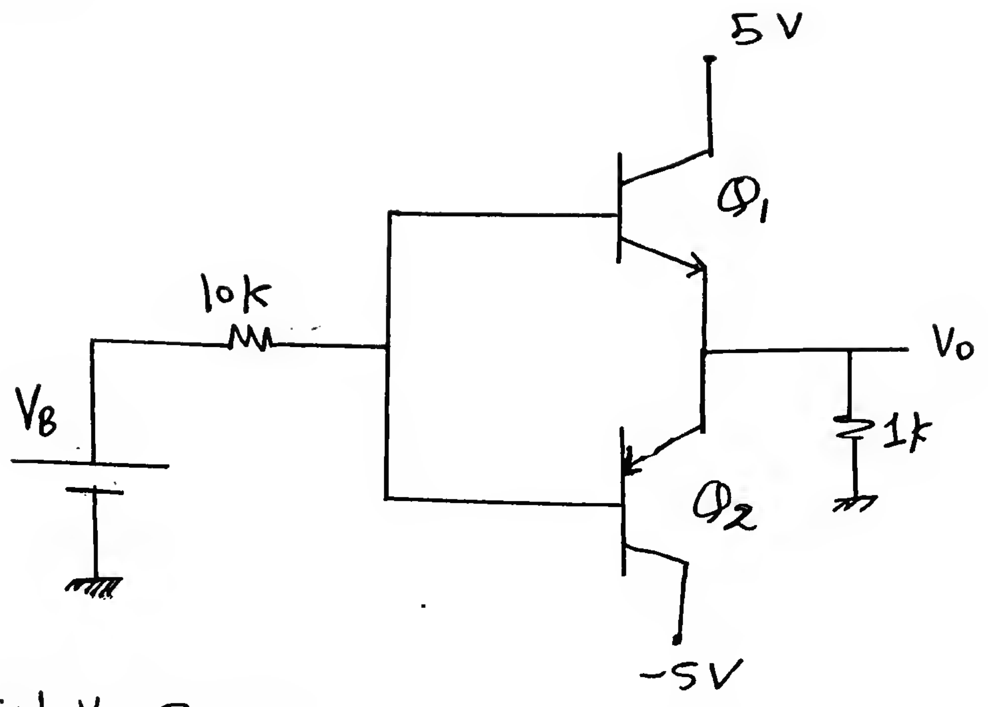
$$I_E = 0.9 \text{ mA}$$

$$I_C = \frac{\beta}{1+\beta} I_E$$

$$I_C = 0.89 \text{ mA}$$

Q-point ($I_C = 0.89mA$, $V_{EC} = 0.7V$)
($I_B = 8.9\mu A$, $V_{EB} = 0.7V$)

P6



Find $V_o = ?$ If $V_B = 0V, 5V, -5V$, $\beta = 100$

Soln Note $V_{BE_1} = V_{BE_2}$

Q_1 to be ON needs $V_{BE_1} = 0.7 \longrightarrow npn$

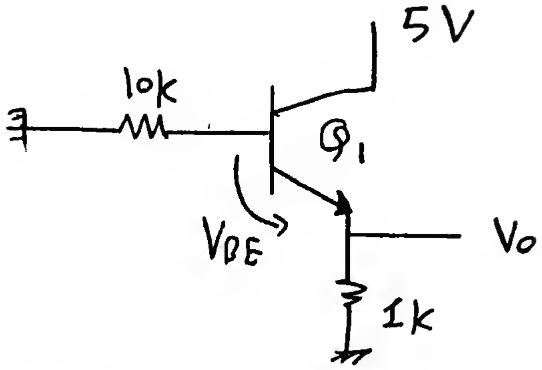
Q_2 to be ON needs $V_{BE_2} = -0.7 \longrightarrow pnp$

So, Q_1 and Q_2 Cannot be ON at the same time

* we have three Conditions $\longrightarrow$
  - Q_1 : ON & Q_2 : off
  - Q_1 : off & Q_2 : ON
  - Q_1 : off & Q_2 : off

$V_{B=0}$:

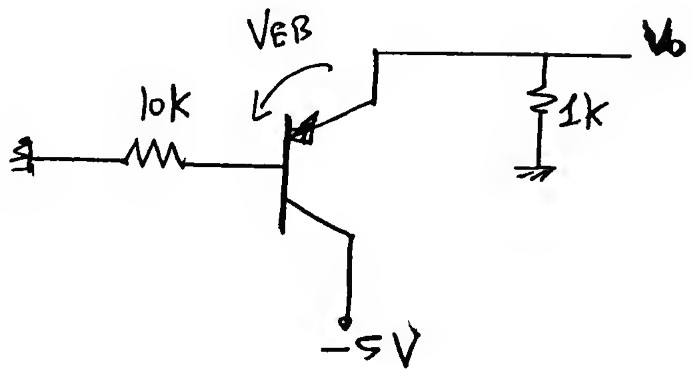
assume Q_1: ON & Q_2: off



V_{BE} Cannot be 0.7 $\longrightarrow$ Q_1 must be off

$\Longrightarrow$ Q_1: ON & Q_2: off (wrong Condition)

assume Q_1: off & Q_2: ON



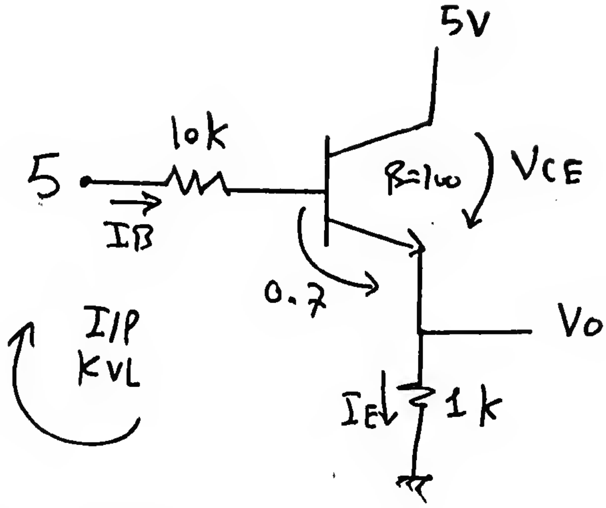
V_{EB} Cannot be 0.7 $\Rightarrow$ Q_2 must be off

$\Rightarrow$ Q_1: off & Q_2: ON (wrong)

when $V_{B=0}$ $\Rightarrow$ Q_1: off & Q_2: off $\Rightarrow$ (V_o = zero)

$V_B = 5\,V$

Q_1: ON & Q_2: off



assume active!

$V_{BE} = 0.7$, $I_C = 100 I_B$, $I_E = 101\, I_B$

I/P kVL:

$$-5 + 10 I_B + 0.7 + 101\, I_B = 0$$

$I_B = 38.7\,\mu A$, $I_C = 3.87\, mA$, $I_E = 3.9\, mA$

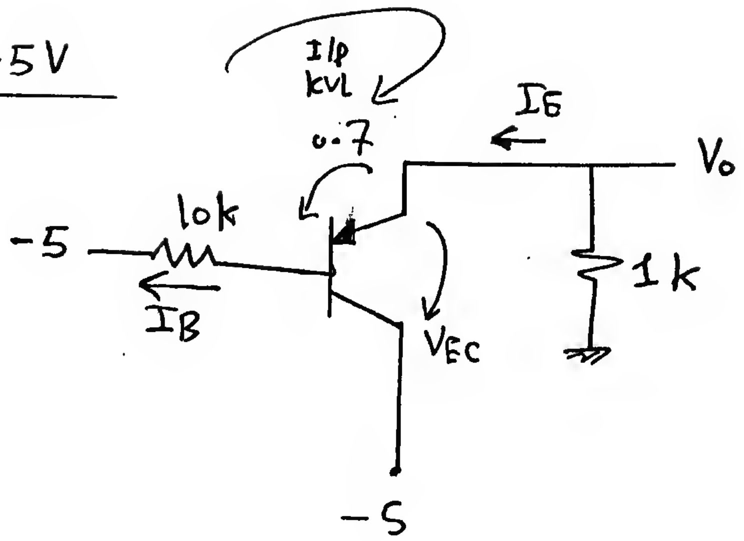
$V_o = I_E(1) = 3.9\, V$

O/P KVL: check

$$-5 + V_{CE} + 3.9 = 0 \Rightarrow V_{CE} = 1.1 > 0.3$$

Active

$V_B = -5V$



assume active!

$V_{EB} = 0.7$, $I_C = 100 I_B$, $I_E = 101\ I_B$, $V_{EC} > 0.3$

I/P KVL:

$$I_E + 0.7 + 10 I_B - 5 = 0$$

$$101 I_B + 0.7 + 10 I_B - 5 = 0 \longrightarrow I_B = 38.7\ \mu A$$

$$I_E = 3.9\ mA$$

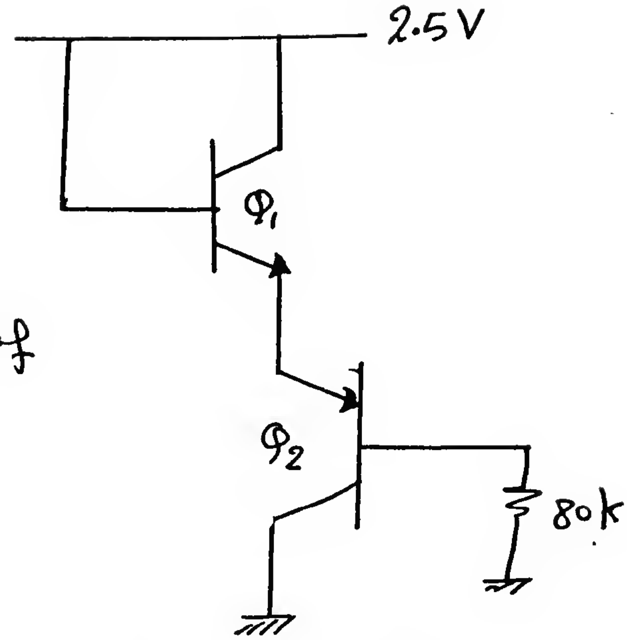
O/P KVL

$$I_E + V_{EC} - 5 = 0$$

$$V_{EC} = 1.1 > 0.3 \Longrightarrow \text{Active}$$

$$\boxed{V_o = -3.9\ V}$$

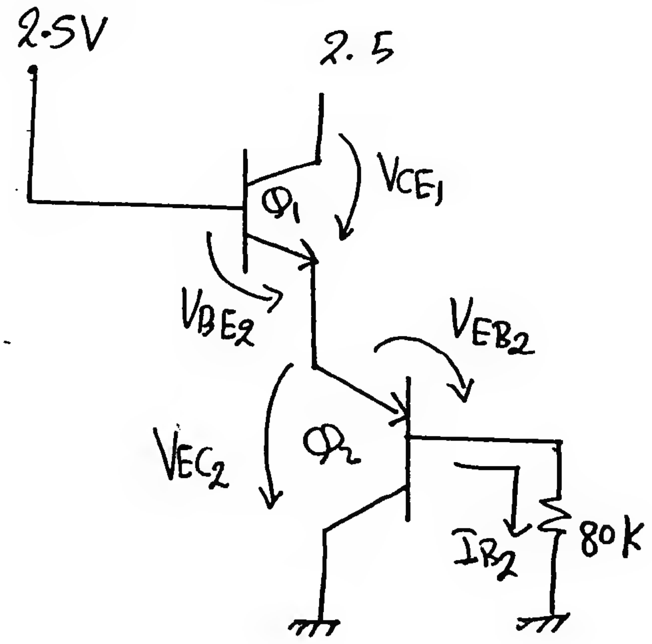
Pb



$\beta = 100$

Find operating point of Q_1 & Q_2

soln



$Q_1 \Rightarrow V_{BE_1} = V_{CE_1} \Rightarrow$ Active $\rightarrow$ $V_{BE_1} = 0.7$, $I_{C_1} = \beta I_{B_1}$, $I_{E_1} = (\beta+1) I_{B_1}$

assume Q_2 is active

$V_{EB_2} = 0.7$, $I_{C_2} = \beta I_{B_2}$, $I_{E_2} = (\beta+1) I_{B_2}$

From circuit $\longrightarrow$ $I_{E_1} = I_{E_2}$

$\downarrow$

$I_{C_1} = I_{C_2} \longrightarrow I_{B_1} = I_{B_2}$

B-E KVL:

$$-2.5 + V_{BE_1} + V_{EB_2} + 80\, I_{B_2} = 0$$

$$-2.5 + 0.7 + 0.7 + 80\, I_{B_2} = 0 \longrightarrow I_{B_2} = 13.75\ \mu A$$

$I_{B_1} = I_{B_2} = 13.75\ \mu A$, $I_{C_1} = I_{C_2} = 1.375\ mA$

C-E KVL:

$$-2.5 + V_{CE_1} + V_{EC_2} = 0 \Rightarrow V_{EC_2} = 2.5 - 0.7 = 1.8\ V > 0.3$$

$\Downarrow$

Active

Q_1-Point $(I_{C_1} = 1.375\ mA,\ V_{CE_1} = 0.7\ V)$

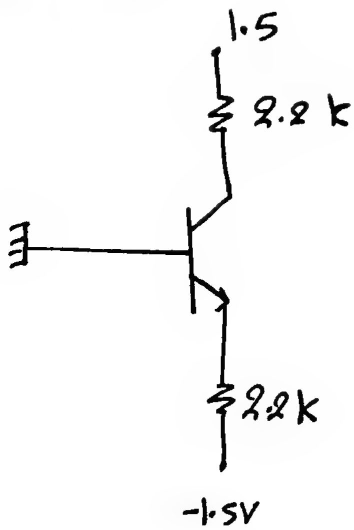
$(I_{B_1} = 13.75\ \mu A,\ V_{BE_1} = 0.7\ V)$

Q_2-Point $(I_{C_2} = 1.375\ mA,\ V_{EC_2} = 1.8\ V)$

$(I_{B_2} = 13.75\ \mu A,\ V_{EB_2} = 0.7\ V)$

#

Pb (1) , Sheet (4)



Find the emitter, base and Collector Voltages and Currents , $\beta = 50$.

Soln

assume Active

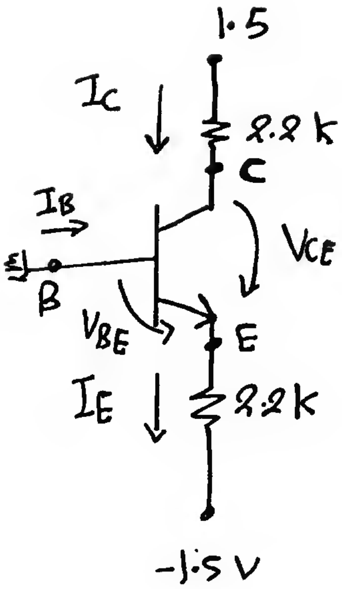
1) $I_C = \beta I_B = 50 I_B$

2) $I_E = (\beta+1) I_B = 51 I_B$

3) $V_{BE} = 0.7$

4) $V_{CE} > 0.3$

I/P KVL :



$V_{BE} + 2.2\, I_E - 1.5 = 0$

$0.7 + 2.2 * 51\, I_B - 1.5 = 0$

$I_B = 7.13\ \mu A$

$I_C = 50\, I_B = 0.356\ mA$

$I_E = 51\, I_B = 0.364\ mA$

O/P KVL :

$-1.5 + 2.2\, I_C + V_{CE} + 2.2\, I_E - 1.5 = 0$

$V_{CE} = 3 - 2.2(0.356) - 2.2\,(0.364) = 1.416$ Volt

$\therefore V_{CE} > 0.3 \Rightarrow$ True assumption.

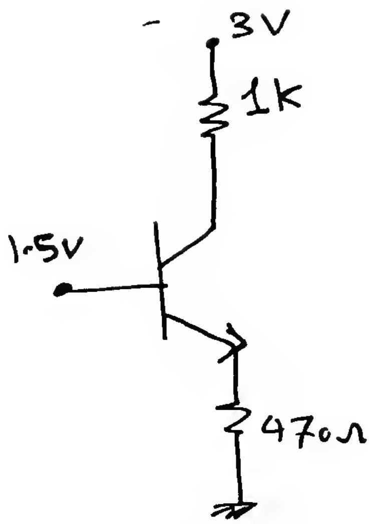
$V_B = 0 \Rightarrow V_{BE} = 0.7 \Rightarrow V_E = -0.7$

$V_{CE} = V_C - V_E = V_C + 0.7 = 1.416 \Rightarrow V_C = 0.716$

$I_B = 7.13\ \mu A$	$V_B = 0$
$I_C = 0.356\ mA$	$V_E = -0.7$
$I_E = 0.364\ mA$	$V_C = 0.716$

Pb2 (Sheet 4)

Find all Currents & Voltages ⟹ $\beta = 50$



Soln

assume Active

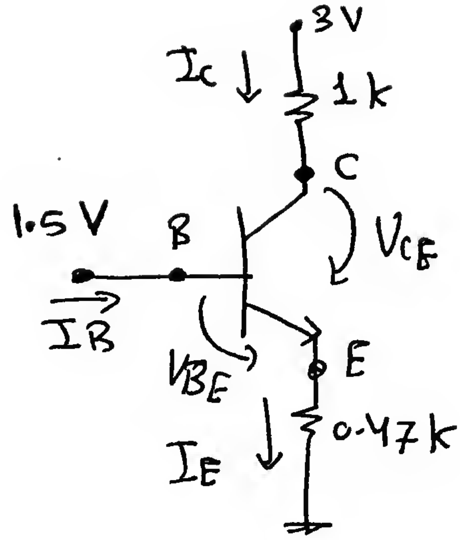
1) $I_C = \beta I_B = 50 I_B$

2) $I_E = (\beta + 1) I_B = 51 I_B$

3) $V_{BE} = 0.7$

4) $V_{CE} > 0.3$

I/P KVL



$-1.5 + V_{BE} + 0.47 * I_E = 0$

$-1.5 + 0.7 + 0.47 * 51 I_B = 0$

$I_B = 33.375\ \mu A$

$I_C = 1.67\ mA$

$I_E = 1.7\ mA$

O/P KVL

$-3 + I_C + V_{CE} + 0.47 I_E = 0$

$V_{CE} = 3 - 1.67 - 0.47 * (1.7) = 0.531$

$\because V_{CE} > 0.3 \Rightarrow$ True assumption

$V_B = 1.5\ V$, $V_{BE} = V_B - V_E = 1.5 - V_E = 0.7$

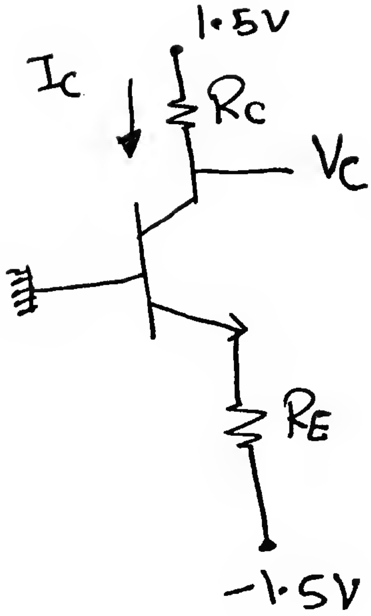
$V_E = 0.8\ V$, $V_{CE} = V_C - V_E = V_C - 0.8 = 0.531$

$\therefore V_C = 1.331$ Volt

Pb3 (Sheet 4)

Design the Circuit to establish $I_C = 0.1\, mA$, $V_C = 0.5\, V$

$\beta = 100$



Note $\quad V_C = 0.5\, V$

* Assume Active $\Rightarrow V_{BE} = 0.7 \Rightarrow V_E = -0.7$

$\therefore V_{CE} = 0.5 + 0.7 = 1.2 > 0.3 \Rightarrow$ True assumption

$$R_C = \frac{1.5 - 0.5}{0.1} = 10\, k\Omega$$

$$I_E = I_C + I_B = I_C + \frac{I_C}{\beta} = \left(1 + \frac{1}{\beta}\right) I_C$$

$$I_E = (1 + 0.01) * 0.1 = 0.101\, mA$$

$$R_E = \frac{-0.7-(-1.5)}{0.101} = 7.9\,k\Omega$$

Pb (4) Sheet (4)

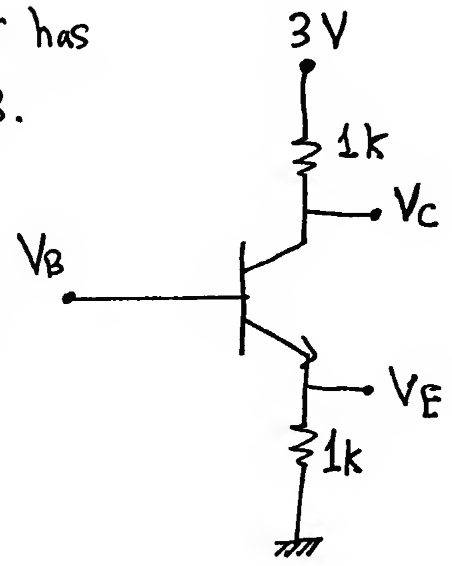
The transistor has very high β.

Find V_E, V_C? for

(a) $V_B = 1.5\,V$

(b) $V_B = 1\,V$

(c) $V_B = 0\,V$



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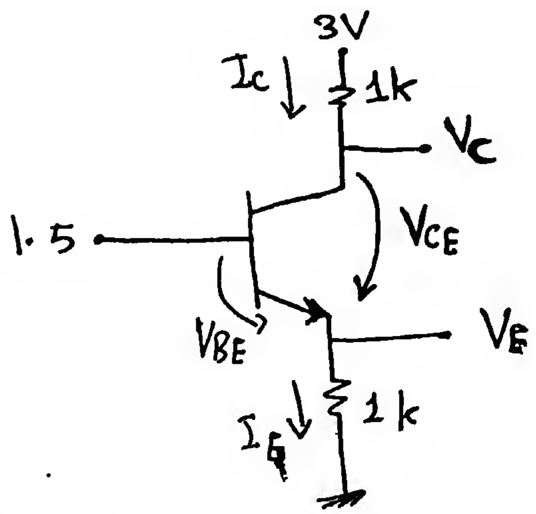
at Very high $\beta \Rightarrow I_B = 0$, $I_C = I_E$

a) $V_B = 1.5\,V$



assume Active :

* $V_{BE} = 0.7$, $V_{CE} > 0.3$

I/P KVL

$-1.5 + V_{BE} + I_E = 0 \Rightarrow -1.5 + 0.7 + I_E = 0$

$\therefore I_E = 0.8\,mA$, $I_C = I_E = 0.8\,mA$

O/P KVL

$-3 + I_C + V_{CE} + I_E = 0 \Rightarrow V_{CE} = 1.4 > 0.3$

$V_{BE} = 1.5 - V_E = 0.7 \Rightarrow V_E = 0.8$ Volt

$V_{CE} = V_C - V_E = V_C - 0.8 = 1.4 \Rightarrow V_C = 2.2$ Volt #

b) for $V_B = 1V$ — Same as the previous case; start from I/P KVL

I/p KVL:

$$-1 + V_{BE} + I_E = 0 \implies I_E = 0.3\,mA$$

$$I_C = I_E = 0.3\,mA$$

O/P KVL

$$V_{CE} = 3 - I_C - I_E = 2.4 > 0.3 \implies$$

$$V_C = 3 - 0.3 = 2.7 \quad , \quad V_E = 0.3 .$$

---

c) for $V_B = 0$ Volt

$$I_E = I_B = I_C = 0 \quad , \quad V_C = 3\text{ Volt}, \quad V_E = \text{Zero Volt}$$

So, we can conclude as V_B decreases.

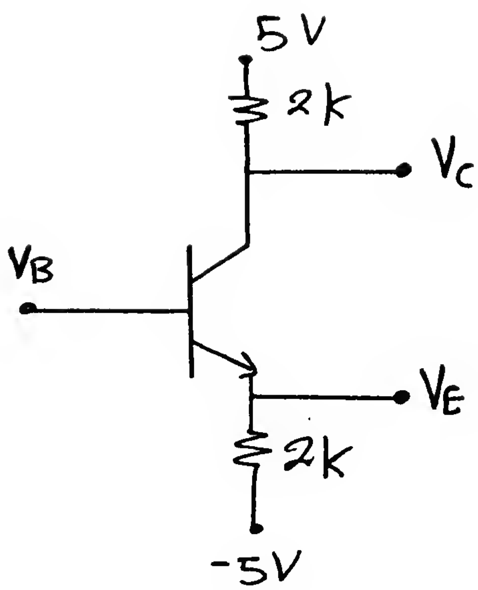
$V_C \uparrow$, $V_E \downarrow$

Pb5 (Sheet3) :

* β very high
(i) Find V_C and V_E = ?
a] $V_B = -1V$

b] $V_B = 0V$

c] $V_B = 1V$



Soln

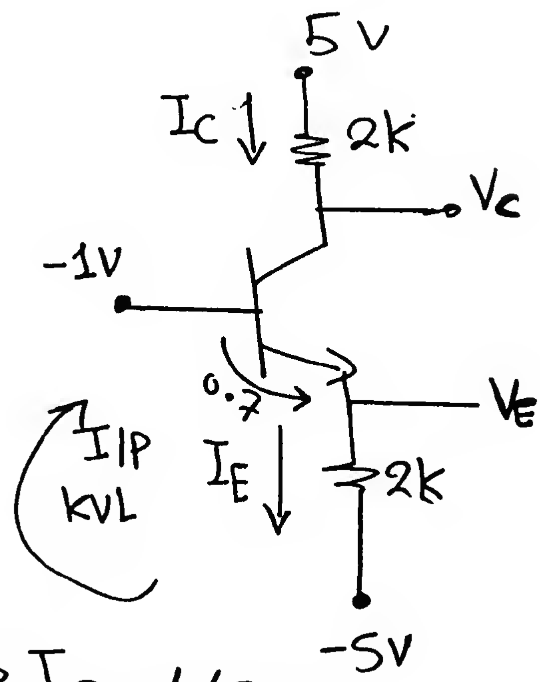
a] $V_B = -1V$

* $I_C = I_E$

* Assume Active

$V_{BE} = 0.7$, $V_{CE} > 0.3$

I/P KVL



$$1 + 0.7 + 2I_E - 5 = 0 \rightarrow I_E = 1.65\,mA$$

$I_E = I_C = 1.65\,mA$

$V_C = 5 - 2I_C = 5 - 2(1.65) = 1.7$ Volt

$V_E = -1 - 0.7 = -1.7$

$V_{CE} = V_C - V_E = 3.4 > 0.3 \Rightarrow$ True assumption

b) $V_B = 0V$

I/P KVL $\quad 0.7 + 2I_E - 5 = 0 \longrightarrow I_E = I_C = 2.15\ mA$

$V_C = 5 - 2(2.15) = 0.7$

$V_E = 0 - 0.7 = -0.7$

$V_{CE} = 1.4 > 0.3 \longrightarrow$ Active

c) $V_B = 1V$:

I/P KVL : $-1 + 0.7 + 2I_E - 5 = 0 \Rightarrow I_E = 2.65\ mA = I_C$

$V_C = 5 - 2(2.65) = -0.3\ V.$

$V_E = 1 - 0.7 = 0.3\ V$

$V_{CE} = -0.6 < 0.3 \Rightarrow$ not active X

Now, assume saturation

$V_{CE} = 0.3$

O/P KVL:

$-5 + 2I_C + 0.3 + 2I_C - 5 = 0 \longrightarrow I_C = 2.425\,mA$

$V_C = 5 - 2(2.425) = 0.15\,V$

$V_E = -0.15\,V$

$V_{BE} = 1 - (-0.15) = 1.15 > 0.8 \Rightarrow$ True assumption

(ii) Find $V_B = ?$ such that $I_E\Big|_{V_B} = \dfrac{I_E}{10}\Big|_{V_B=0}$

Soln $V_B = 0\,V \longrightarrow I_E = 2.15\,mA$

$I_E\Big|_{V_B} = 0.215\,mA$

O/P KVL: $-5 + 2(0.215) + V_{CE} + 2(0.215) - 5 = 0$

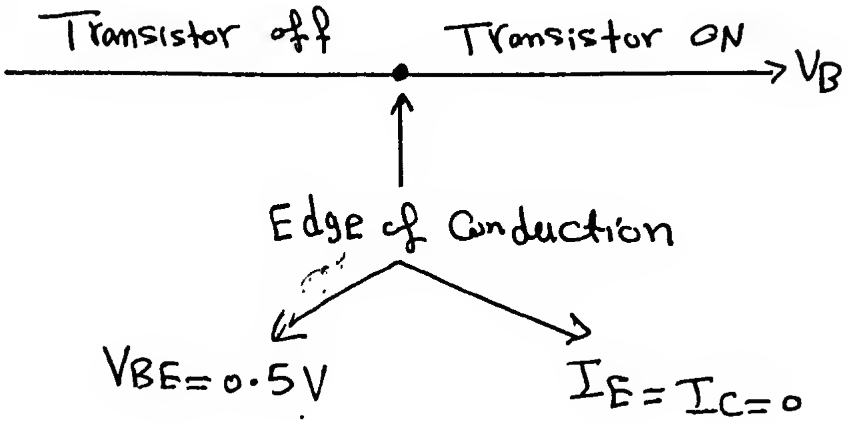
$V_{CE} = 9.14 > 0.3 \Rightarrow$ Active

$V_{BE} = 0.7 \Rightarrow V_B = V_E + 0.7 = 2(0.215) - 5 + 0.7$

$$\boxed{V_B = -3.87\,V}$$

$V_B = ?$ $\longrightarrow$ Transistor at the edge of Conduction then find V_E & $V_C = ?$

Soln



I/P KVL:

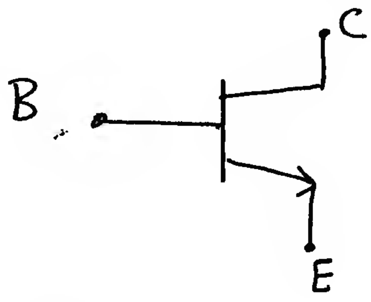
$$-V_B + 0.5 - 5 = 0 \longrightarrow V_B = 4.5\,V$$

$V_C = 5V$

$V_E = -5V$

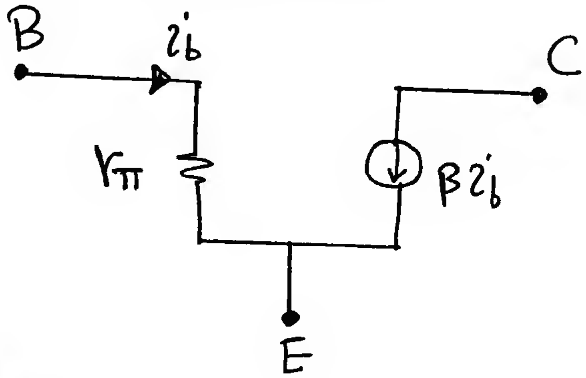
---

* BJT small signal model :



There is three models :

1)

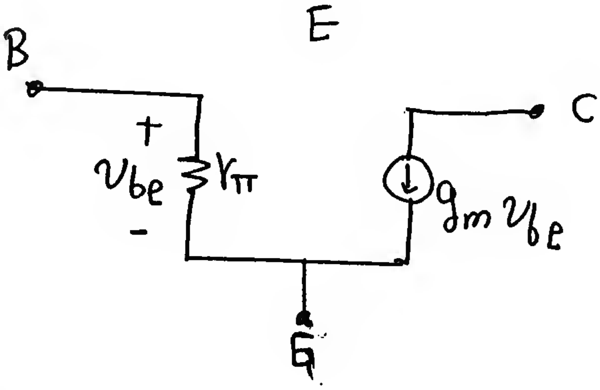


$$r_\pi = \frac{V_T}{I_B} = \frac{\beta V_T}{I_C}$$

V_T → 26mv

I_B, I_C → DC analysis

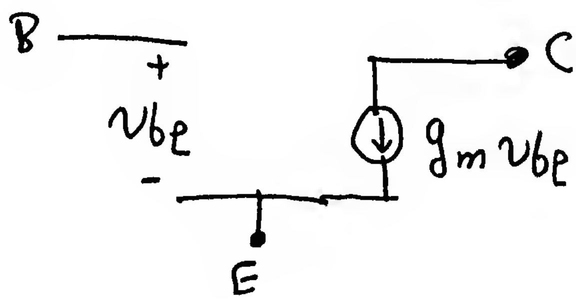
2)



$$g_m = \frac{\beta}{r_\pi} = \frac{I_C}{V_T}$$

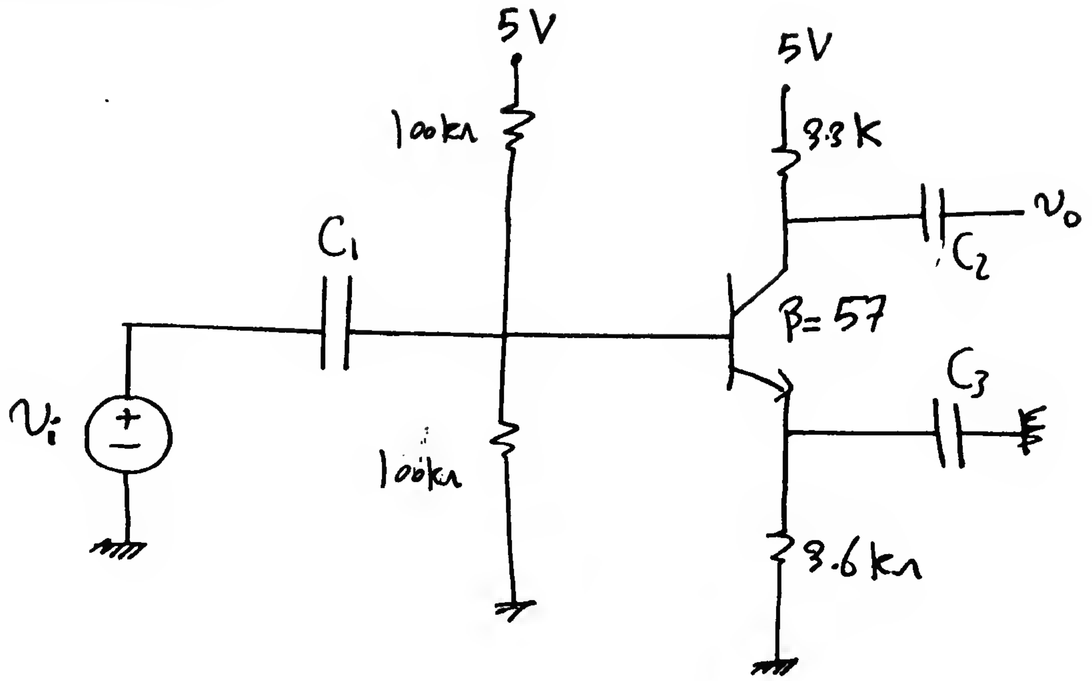
V_T → 26mv

3) β Very Large or infinity



$$g_m = \frac{\beta}{r_\pi} = \frac{I_C}{V_T}$$

Pb6 (Sheet 4)



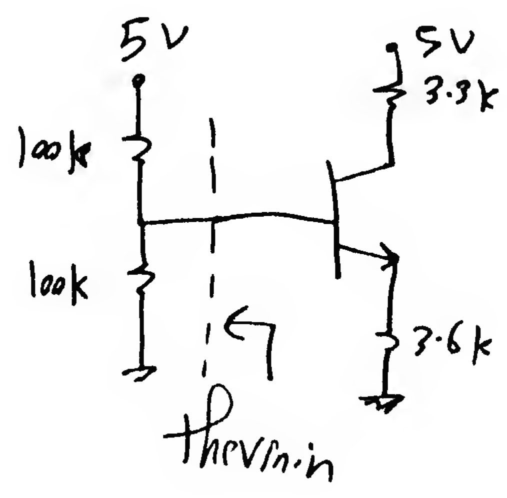
1) Find I_C, V_{CE} ?

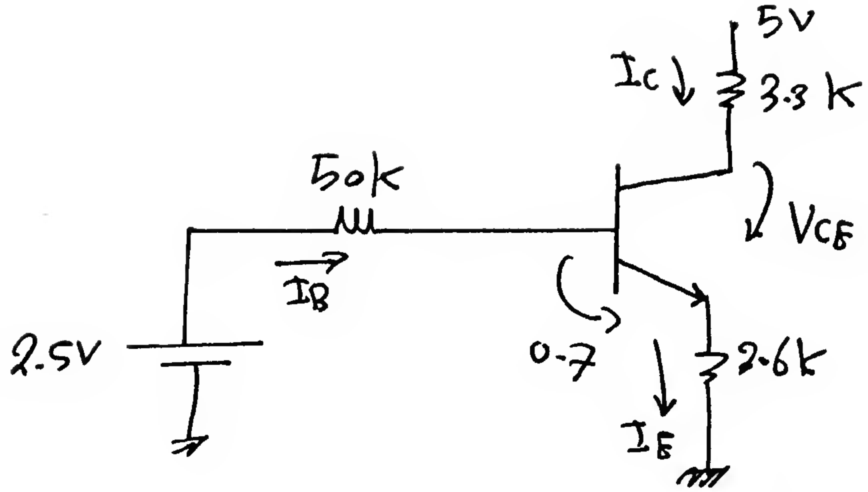
2) Find A_v in ratio and dB ?

Soln DC circuit

1) Deactivate v_i

2) —||— → _/ o.c





I/P KVL

$$-2.5 + 50\,I_B + 0.7 + 3.6\,(58\,I_B) = 0$$

$$I_B = 6.955\ \mu A \implies I_C = 0.396\ mA$$

$$I_E = 0.4\ mA$$

O/P KVL

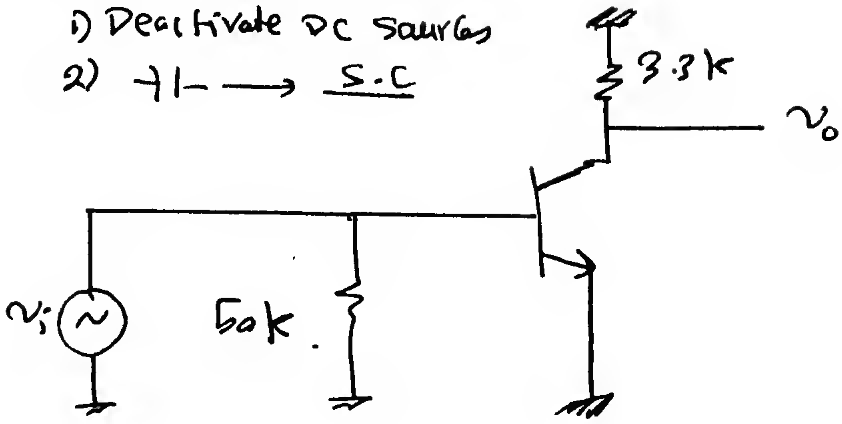
$$-5 + 3.3 * (0.396) + V_{CE} + 3.6\,(0.4) = 0$$

$$V_{CE} = 2.2532\ \text{Volt}$$

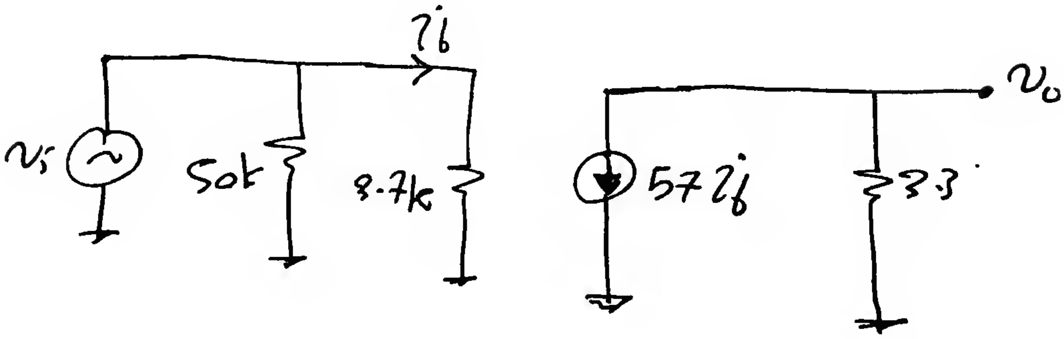
$$r_\pi = \beta \frac{V_T}{I_C} = 57 * \frac{26}{0.396} \simeq 3.7\ k\Omega$$

AC circuit:

1) Deactivate DC sources
2) $\dashv\vdash \longrightarrow$ S.C



* Small signal circuit:

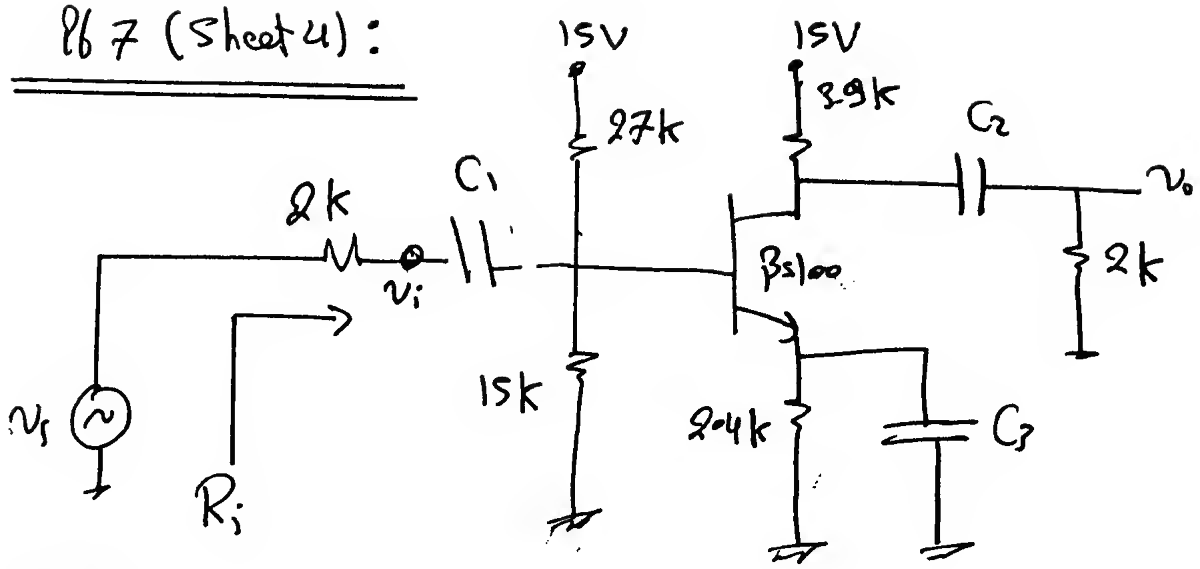


$$V_o = -3.3 * 57 i_b$$

$$V_i = 3.7 i_b$$

$$A_v = \frac{v_o}{v_i} = -50.84 \quad , \quad A_v|_{dB} = 34.12 \text{ dB}$$

P6 7 (Sheet 4):

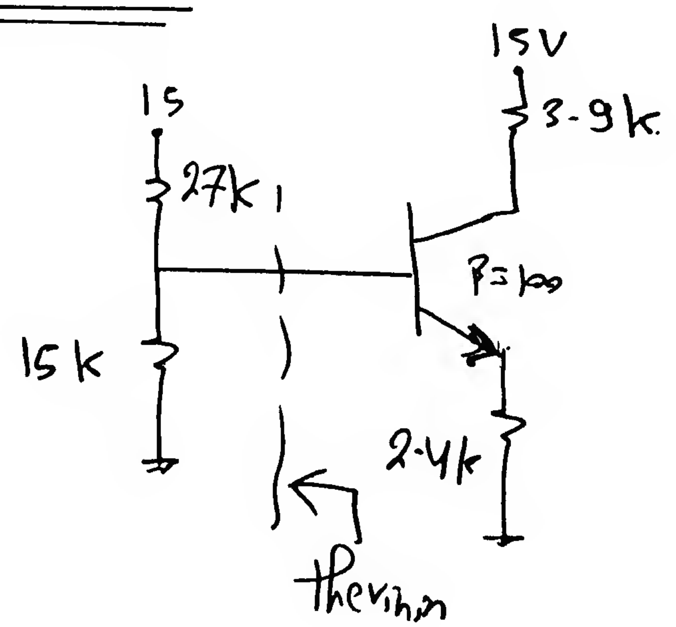


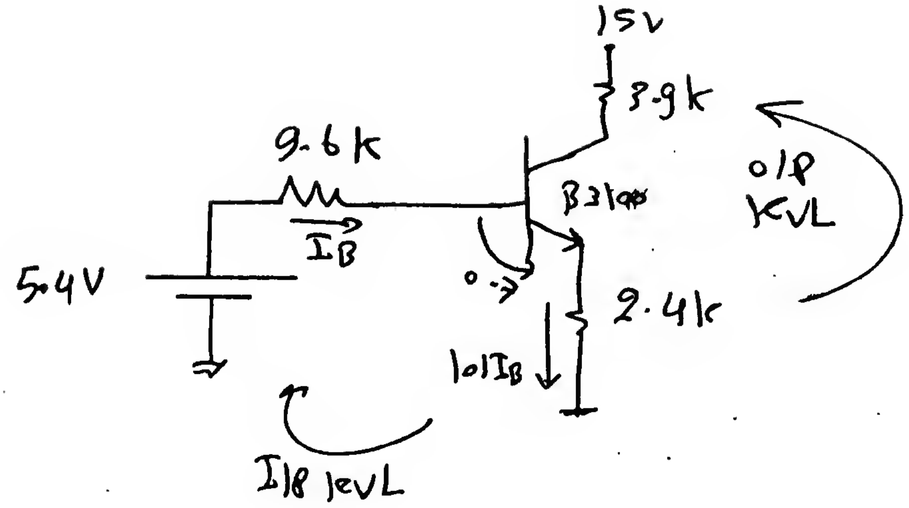
Find

1) R_i
2) $\frac{v_o}{v_i}$
3) $\frac{v_o}{v_s}$
4) $v_o = ?$ if $v_s = 1\ mV$

Soln

DC circuit





I/p KVL

$$-5.4 + 9.6 I_B + 0.7 + 101 I_B * 2.4 \Longrightarrow I_B = 18.65 \mu A$$

$I_C = 1.865$ mA , $I_E = 1.88$ mA

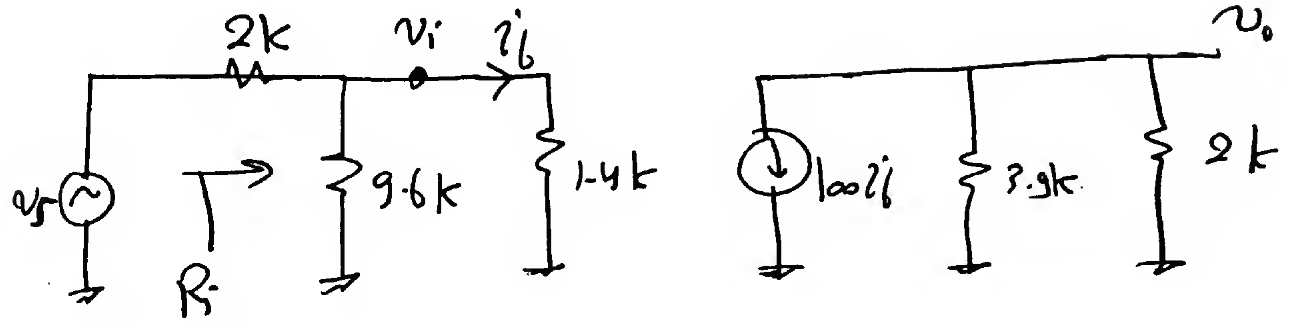
o/p KVL

$$-15 + 3.9 * 1.865 + V_{CE} + 2.4 * 1.88 = 0$$

$$V_{CE} = 3.2145$$

$$r_\pi = \beta \frac{V_T}{I_C} = 100 \frac{26}{1.865} \approx 1.4 k\Omega$$

* Small signal Circuit :



$R_i = 9.6 \,//\, 1.4 = 1.22\ k\Omega$

$v_o = -100 i_b * 3.9 \,//\, 2 = -132.2\, i_b$

$v_i = 1.4\, i_b$

$v_s = \left(i_b + \frac{1.4 i_b}{9.6} \right) * 2 + 1.4 i_b = 3.69\, i_b$

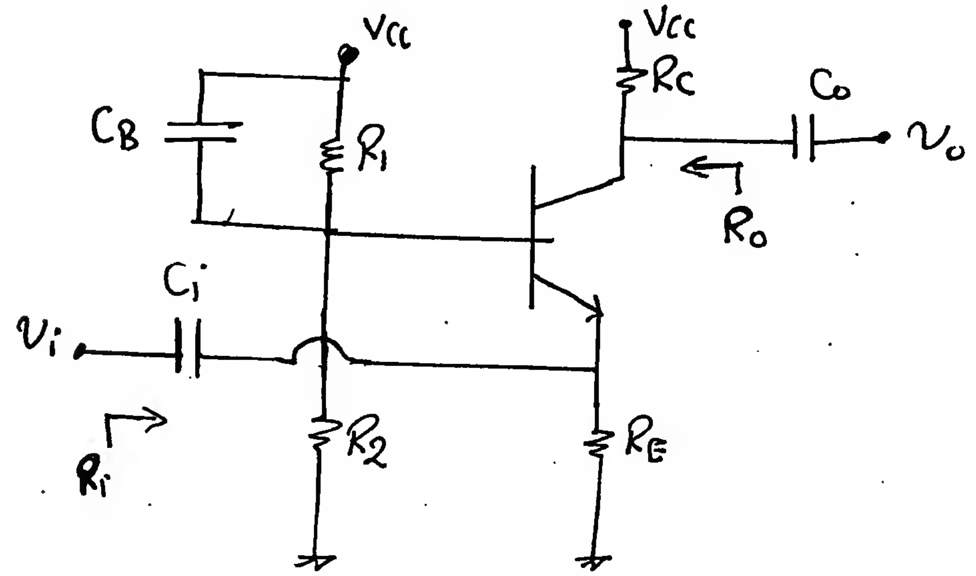
$\frac{v_o}{v_i} = -94.4$, $\frac{v_o}{v_s} = -35.8$

$v_s = 1\ mV \Rightarrow v_o = -35.8\ mV$

#

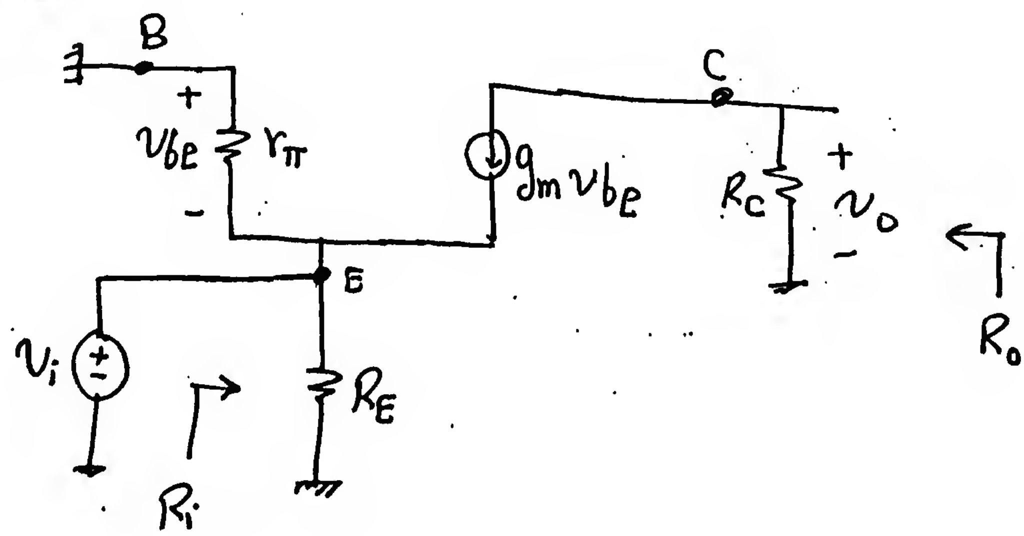
* BJT Common base amplifier :

* Input at emitter and output at Collector
* Base is common between input and output



Find A_v, A_i, R_i, R_o

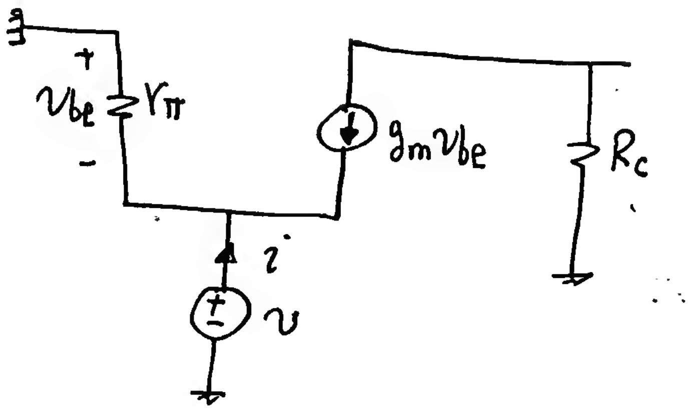
Solⁿ



1) $v_i = -v_{be}$, $v_o = -g_m R_C v_{be}$

$$A_v = \frac{v_o}{v_i} = g_m R_C > 1$$

2) $R_i = R_E // R'$, $R' = ?$



$$R' = \frac{v}{i} = \frac{-v_{be}}{-g_m v_{be} - \frac{1}{r_\pi} v_{be}} = \frac{1}{g_m + \frac{1}{r_\pi}}$$

$$R' = \frac{1}{g_m} // r_\pi$$

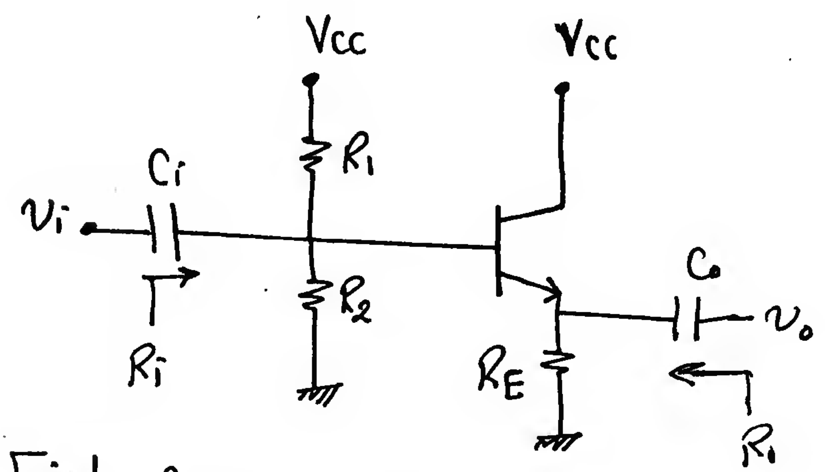
$R_i = R_E // \frac{1}{g_m} // r_\pi$, Note $r_\pi = \frac{\beta}{g_m}$

$r_\pi >> \frac{1}{g_m} \Rightarrow \frac{1}{g_m} // r_\pi \approx \frac{1}{g_m}$

$R_i \simeq R_E // \frac{1}{g_m}$, $R_o = R_C$, $A_i = A_v \frac{R_i}{R_C} = \frac{g_m R_E}{1 + g_m R_E} \simeq 1$

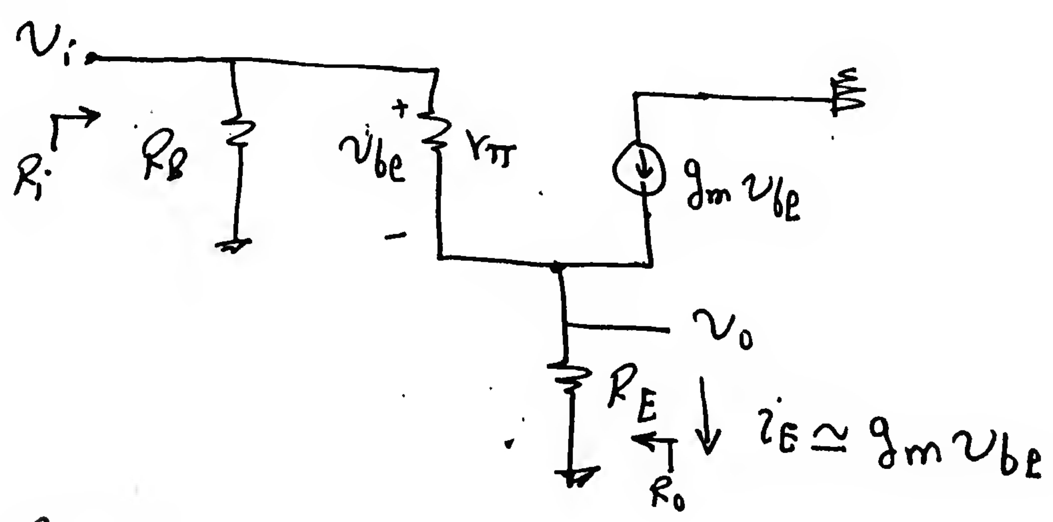
* BJT Common Collector Amplifier :

* Input at base & output at emitter
* Collector is common between i/p & o/p



Find A_v, A_i, R_i, R_o

Soln: $R_B = R_1 \parallel R_2$



$$v_i \simeq v_{be} + g_m v_{be} R_E = (1 + g_m R_E) v_{be}$$

$$v_o \simeq g_m R_E v_{be}$$

$$A_v \simeq \frac{g_m R_E}{1 + g_m R_E} < 1$$

$$\text{If } g_m R_E >> 1 \implies A_v \simeq 1$$

$$R_i = R_B \,//\, R' \quad , \quad R' = \frac{v}{i} = \frac{(1+g_m R_E)\, v_{be}}{v_{be}/r_\pi}$$

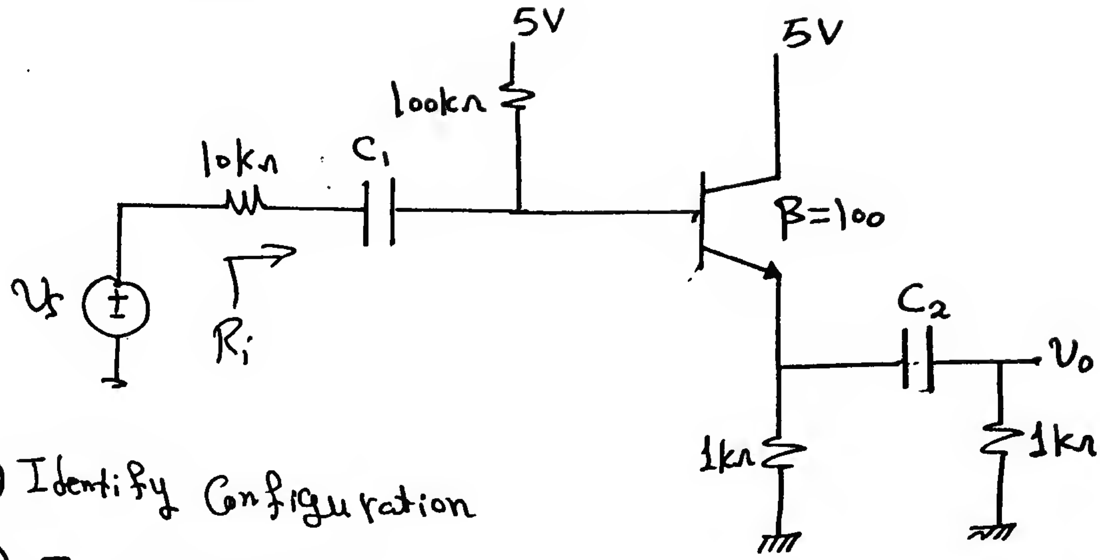
$$R' = r_\pi (1+g_m R_E) = (r_\pi + \beta R_E)$$

$$R_i \simeq R_B \,//\, [r_\pi + \beta R_E]$$

$$R_o = R_E \,//\, r_\pi \,//\, \frac{1}{g_m} \simeq R_E \,//\, \frac{1}{g_m}$$

$$A_i = A_v * \frac{R_i}{R_E} \simeq \frac{R_B \,//\, [r_\pi + \beta R_E]}{R_E} \simeq \frac{R_i}{R_E}$$

Pb3 (Sheet 5):



1) Identify Configuration
2) I_E, V_E and V_B
3) R_i
4) v_o/v_s

Soln

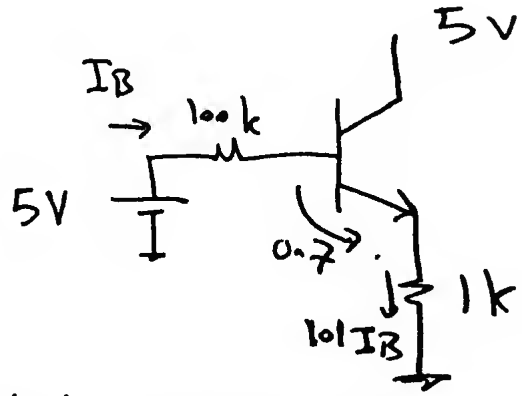
I/P at base
O/P at emitter

$\Rightarrow$ Common Collector
$\Rightarrow$ Emitter-follower

DC analysis

I/P KVL:

$$-5 + 100 I_B + 0.7 + 101 I_B = 0$$

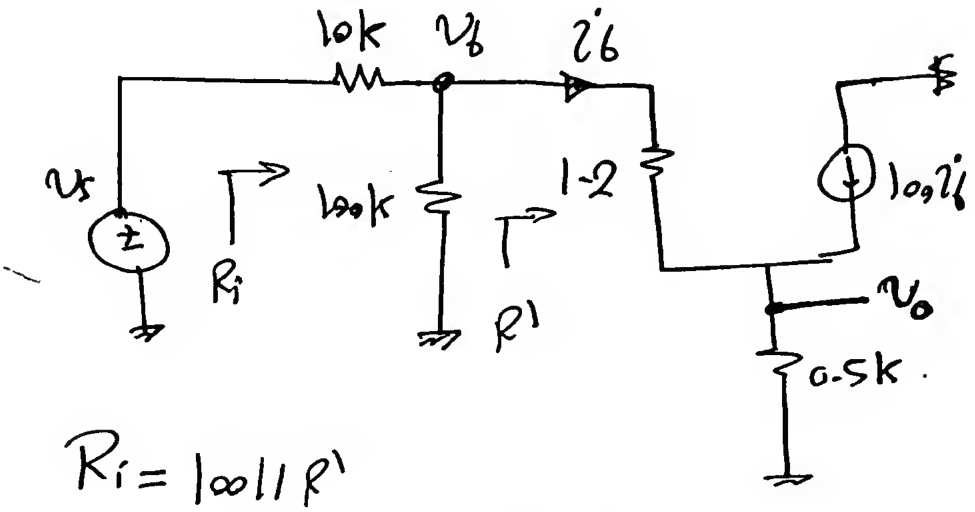


$$I_B = 0.0214 \text{ mA}$$

$I_E = 2.16$ mA, $V_E = 2.16$ V, $V_B = 2.86$ V

$$r_\pi = \frac{V_T}{I_B} = \frac{26mv}{0.0214} = 1.2\,k\Omega$$

* **Small signal model :**



$$R_i = 100 // R'$$

$$R' = \frac{v_b}{i_b} = \frac{1.2\, i_b + 101.2\, i_b * 0.5}{i_b} = 51.8\,k\Omega$$

$$R_i = 100 // 51.8 \simeq 34\,k\Omega$$

$$v_o = 101.2\, i_b * 0.5 \longrightarrow (1)$$

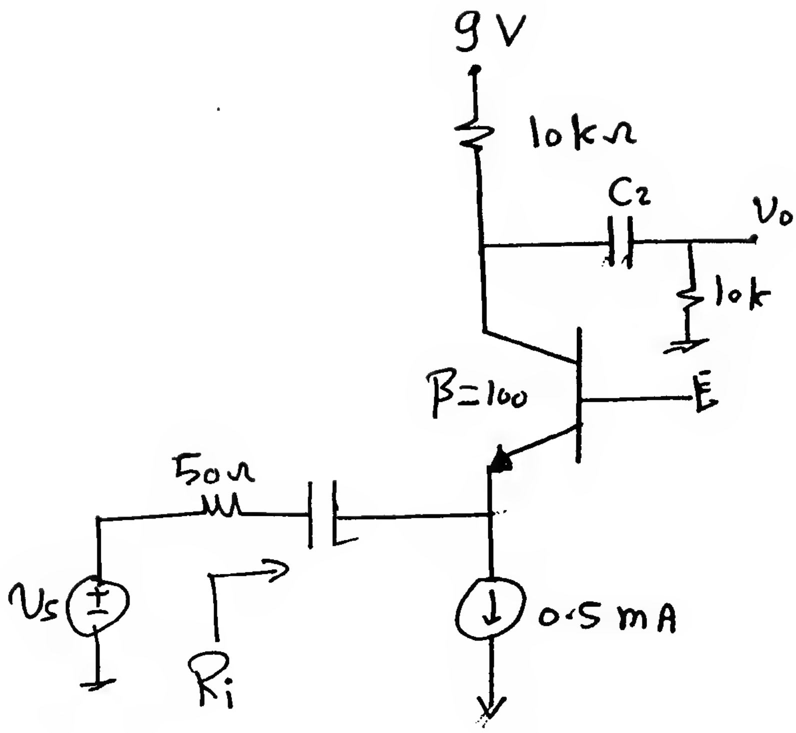
$$v_b = v_s * \frac{R_i}{10 + R_i} = \frac{34}{44} v_s \Rightarrow v_s = \frac{44}{34} v_b \rightarrow (2)$$

$$\frac{v_o}{v_s} = 101.2 * 0.5 * \frac{34}{44} \frac{i_b}{v_b} = 101.2 * 0.5 * \frac{34}{44} * \frac{1}{51.8}$$

$$\frac{v_o}{v_s} = 0.75$$

Pb4 (Sheet 5)

* Find R_i = ?
* Find v_o/v_{sig} = ?



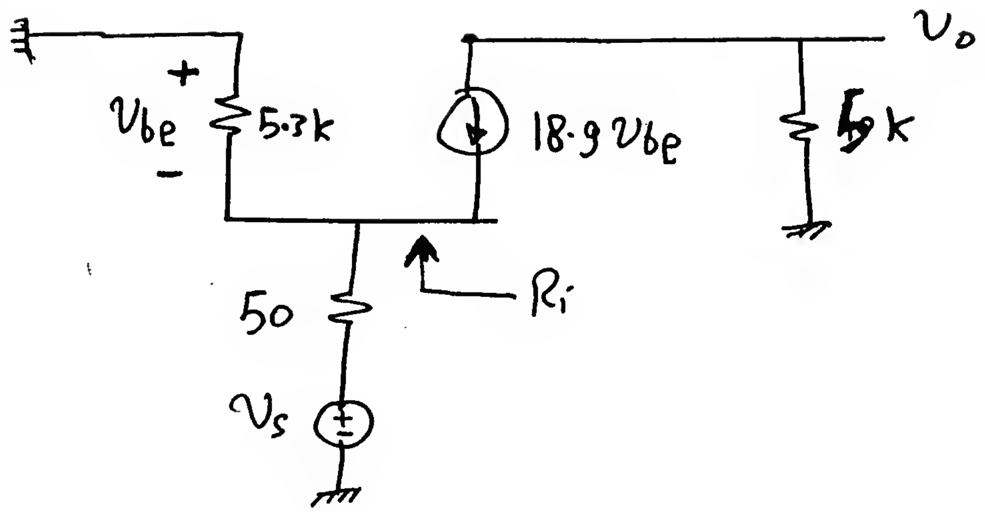
Soln

DC analysis ⟶ $I_E = 0.5\,mA$

$$I_B = \frac{I_E}{\beta+1} = \frac{0.5}{101} = 4.95\,\mu A$$

$$r_\pi = \frac{V_T}{I_B} = \frac{26\,mV}{4.95\,\mu A} \simeq 5.3\,k\Omega$$

$$g_m = \frac{\beta}{r_\pi} = \frac{100}{5.3} \simeq 18.9\,mA/V$$



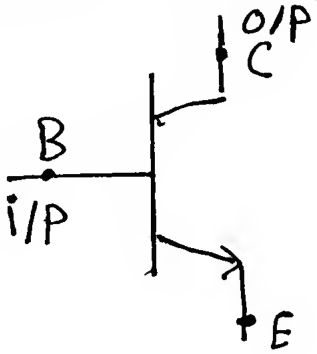
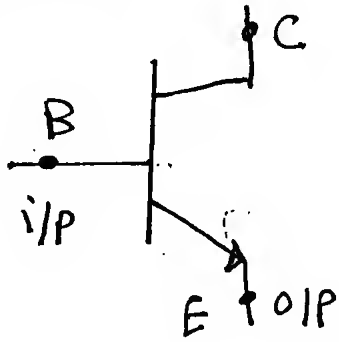
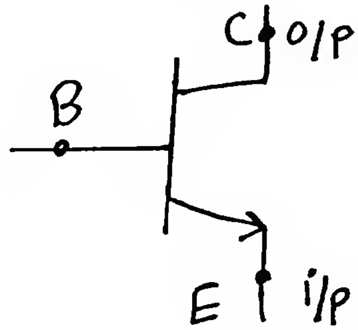
$$R_i = 5.3 \,//\, \frac{1}{18.9} \simeq \frac{1}{18.9}\,k \simeq 52\,\Omega$$

$$v_{be} = -v_s * \frac{R_i}{50 + R_i} \rightarrow v_s \simeq -2\,v_{be}$$

$$v_o = -18.9\,v_{be} * 5$$

$$\frac{v_o}{v_s} = \frac{-18.9\,\cancel{v_{be}} * 5}{-2\,\cancel{v_{be}}} = 47.25 \quad \#$$

* Compare between Common emitter, Common collector & Common-base.

CE	CC (Emitter follower)	CB
		
$A_v \uparrow\uparrow$	$A_v \simeq 1$	$A_v \uparrow\uparrow$
$R_i \sim k\Omega$ $R_o \sim k\Omega$	$R_i \sim 100k\Omega \uparrow$ $R_o \sim \Omega \downarrow$	$R_i \sim \Omega \downarrow$ $R_o \sim k\Omega$
Used as Voltage amplifier	Used as Buffer	Used as current amplifier

Note Ideal CC → $A_v = 1$
Ideal Buffer $R_i = \infty$
R_o = Zero